AIR FORCE RESEARCH LABORATORY [AFRL]
Manager of the Basic Research Investment for the Air Force Research Laboratory

Research

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NU Professor Crosses Line to Faster Computer Circuits

AN ARTICLE PUBLISHED IN THE "CHICAGO SUN TIMES" BY NEIL STEINBERG ON JANUARY 29, 1999

A tiny, tiny line drawn by a whisp of a quill pen attached to a computerized microscope at Northwestern University might be the key to development of faster computer circuits and needle-tip sized medical probes in the future.

"What we've done is miniatured 4,000-year-old technology," said Chad A. Mirkin, the Morrison professor of Chemistry at Northwestern, whose research, aided by several students and post-doctoral candidate co-authors, is being published today in the journal *Science*.

The researchers — sponsored by the Air Force Office of Scientific Research and the National Science Foundation — made a small quill pen out of a tip of silicon nitride, then used an atomic force microscope to guide the pen to produce the thinnest lines ever drawn: 15 nanometers — or billionths of a meter — wide. The smallest electronic circuits now in development are about 180 nanometers, and a fine human hair is about 10,000 nanometers thick.

The ink is first allowed to dry on the pen tip, then the tip is brought in contact with the surface — in this case, a gold mirrored foil.

"A small amount of water condenses in capillary from the tip to the surface," said Mirkin, 35. "The ink travels to the water, to the paper, which in this case is gold."

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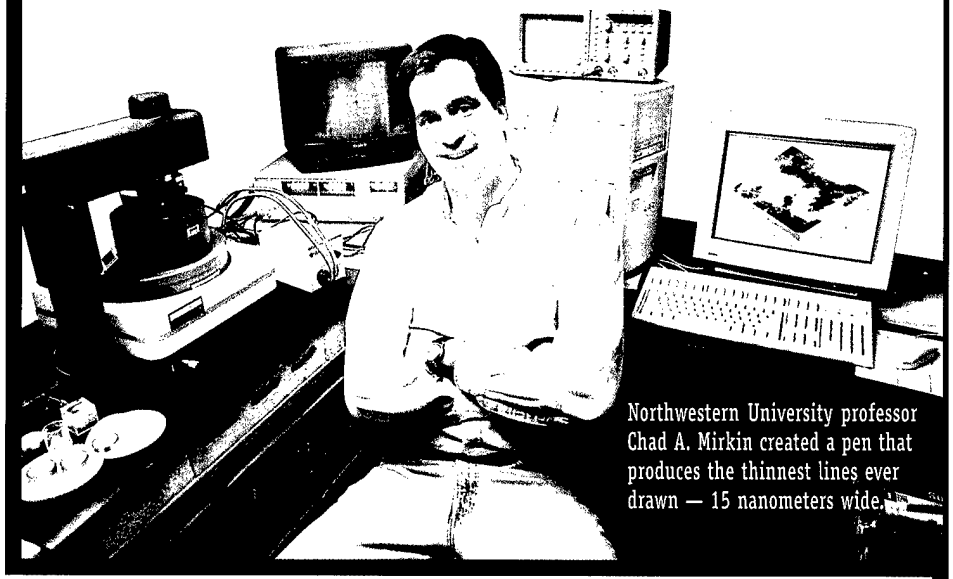

Northwestern University professor Chad A. Mirkin created a pen that produces the thinnest lines ever drawn — 15 nanometers wide.

AIR FORCE TO BENEFIT WITH SMALLER, LIGHTER, LESS COSTLY SYSTEMS

Invention of this novel tool, using dip-pen nanlithography (DPN) — which has created the world's smallest pen — will catalyze many advances in the emerging areas of nanotechnology and molecule-based electronics. This advance will enhance the possibility of future Air Force weapon systems becoming smaller, lighter, and less expensive.

Specifically, DPN is the missing link in the nanotechnology arena that will allow development of smaller, lighter weight, faster, and more reliably produced:

- electronic circuits and devices,
- high-density storage materials, and
- sensory structures.

Use of the technology could possibly be used to create many small-scale sensors and power assemblies mounted on a single chip for use on micro-satellites or mounted within an Unmanned Aerospace Vehicle (UAV). The savings in launch weight provides for significant savings in launch costs.

Microelectronics have always been limited by the size of the components that make up a device. That limitation may now have been breached by the invention of a new tool for preparing molecule-based nanostructures. "Dip Pen Nanolithography" (DPN) was recently invented by Northwestern Researchers with the help of an AFOSR funding grant.

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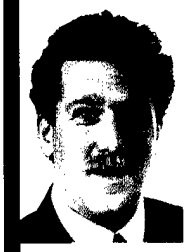
AFOSR-Funded University Researchers Receive Presidential Award

Two researchers supported by the Air Force Office of Scientific Research received the prestigious Presidential Early Career Award for Scientists and Engineers (PECASE). This award is the highest honor bestowed by the United States government on young professionals at the outset of their independent research careers.



Dr. Blumenthal

Dr. Dickey

The award, presented in February by Dr. Neal Lane, the President's Science Advisor, includes a five-year $500,000 research grant.

The two AFOSR-sponsored researchers, Drs. Daniel Blumenthal from the University of California-Santa Barbara and Elizabeth Dickey from the University of Kentucky, were recognized for their efforts in conducting top quality research in areas of critical importance to the Air Force.

"These researchers have made important contributions to the entire AFRL community," said Dr. Joe Janni, AFOSR Director. "Although their research is considered 6.1, the entire lab community benefits from the work of these two fine researchers."

Dr. Blumenthal

Dr. Blumenthal is a professor in the Electrical and Computer Engineering department at the University of California — Santa Barbara. He received his doctorate from the University of Colorado at Boulder in 1993.

"Dr. Blumenthal's work on multi-wavelength optical techniques for data processing and transmission offers a basis for increases by a factor of 1,000 in data storage and bandwidth," said Dr. Jack Agee, Director of AFOSR's Physics and Electronics Directorate.

"For the Air Force, this offers dramatic improvements in three-dimensional video display from distributed sensors and archives. The payoffs are exciting applications to real-time battle visualization and management, use of space-based sensors, and to computers and communications," Agee added.

Dr. Blumenthal's work offers the Air Force an opportunity for dramatic improvements in three-dimensional video displays.

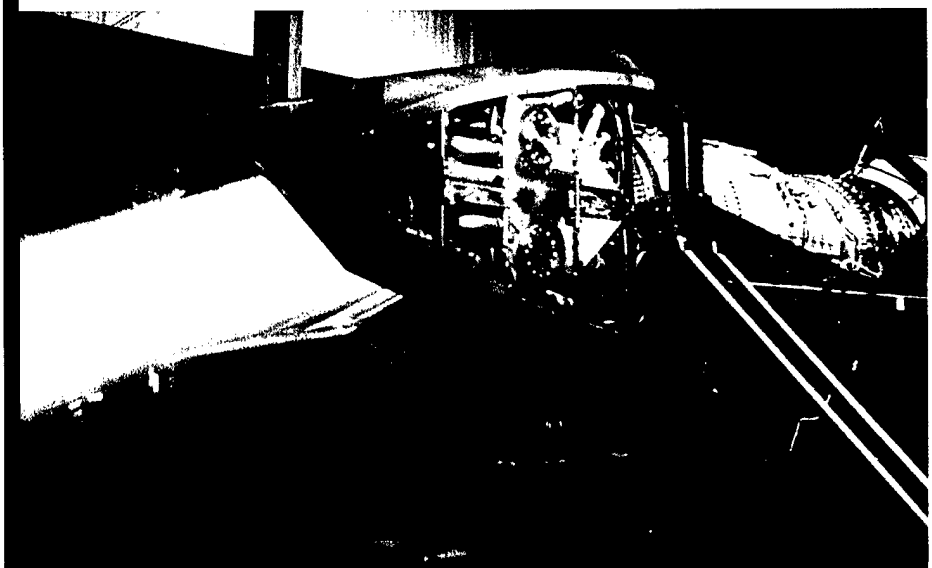
Dr. Dickey

The second award winner, Dr. Elizabeth Dickey is a professor in the Chemical and Materials Engineering department at the University of Kentucky. She received her doctorate from Northwestern University in 1997.

"Professor Dickey has developed a number of techniques for characterizing interfaces in materials, particularly high temperature ceramic materials. Her command of electron microscopy, X-ray diffraction, and neutron diffraction has brought some important insights into the structure of interfaces," said Dr. Alex Pechenik, Acting Director of AFOSR's Aerospace and Materials Sciences Directorate.

"She has the potential of becoming one of the leading researchers in the field of high-temperature materials in the near future. Her collaboration with many researchers at AFRL, working on designing new, improved high-temperature materials for turbine and rocket engines, makes her work very valuable for the Air Force," he added.

These presidential awards, established by President Clinton in February 1996, embody the high priority the Administration places on producing outstanding scientists and engineers and nurturing their continued development. Eight federal departments join together annually to nominate the most meritorious young scientists and engineers who will broadly advance science and technology that will be of the greatest benefit to the participating government agencies.



Dr. Elizabeth Dickey, is working on designing new, improved high-temperature materials that would be used for turbine and rocket engines.

NU Professor Crosses Line to Faster Computer Circuits

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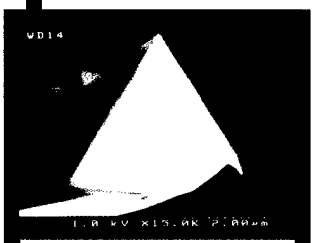
Mirkin said the technology, which is being patented, might someday be useful for printing smaller computer circuits, and right now can be used to modify existing circuits, particularly sensors.

"Say I have a chip set up to be a sensor," he said. "I can put on a component, one molecule at a time, that reacts with, for instance, carbon dioxide."



This new concept in nanolithography is based upon the transport of a chemically reactive material or "ink" from the tip of a conventional silicon nitride Atomic Force Microscope (AFM) to the surface of interest or "paper."

Such sensors, detecting various substances and conditions, can be packed into a very small space.

"A medical device could have 1,000 sensors on the tip of a needle," he said, adding that such delicate devices would be vastly preferable to larger models.

The new technology came from Mirkin's work in the area of modification of surfaces, relating to materials chemistry and nanotechnology.

"We're very interested in being able to create small structures and then study the small structures," he said. " There are going to be a lot of neat discoveries that come out."

(Reprinted with permission from the Chicago Sun Times)

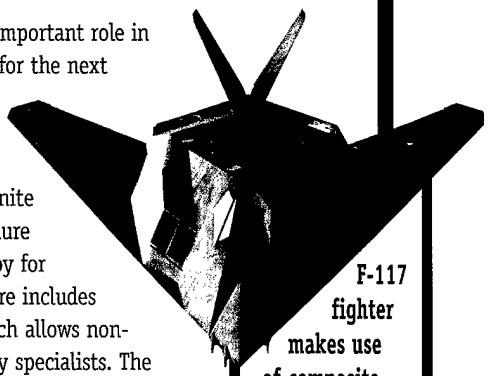
For more information about Dip-pen lithography and how it works see this article on the AFOSR website.

Visit our website at www.afosr.af.mil

Composite Structure Designers Benefit From New Analysis Tools

Customer ..... Aerospace materials scientists and structural engineers now have a new state-of-the-art software product called *Stress Check*, which provides efficient and reliable analysis tools for composite bonded aircraft structures. A composites research team from the aeronautics industry, known as the Composites Affordability Initiative (CAI), has just completed an extensive study of current capabilities in the area of failure analysis tools for composite bonded joints. This study led the CAI team to unanimously choose *Stress Check* as the software tool to replace, as well as radically improve existing industry standard software currently used for sizing bonded joints.

Benefit ..... This new software tool will play an important role in making composites more affordable for the next generation of fighter aircraft. The software provides a highly reliable and user-friendly production stress analysis tool that will replace the Finite Element Method (FEM) tools and failure criteria that experts currently employ for analyzing bonded joints. The software includes an FEM-based handbook format which allows non-experts to utilize models prepared by specialists. The handbook problems include built-in failure criteria, geometric and material nonlinearities, and the modern FEM technology provides better error control and the treatment of very large aspect ratios.



F-117 fighter makes use of composite bonded aircraft structures.

Basic Research ..... This software is based on AFOSR-sponsored research on new failure methodologies for composite materials and modern finite element technology pioneered by Prof. Barna Szabo at Washington University in St. Louis. His work led to the development of the modern p-version of the finite element method with *a posteriori* error control, new hierarchical modeling techniques in elasticity and composite materials, and new failure initiation criteria.

Performer ..... *Stress Check* was developed through a collaboration between the Washington University scientists and Engineering Software Research and Development, Inc. (ESRD) in St. Louis, partially enabled by an AFOSR Phase II STTR contract. The CAI team worked closely with ESRD to recommend modifications to *Stress Check* to ensure its reliability, portability, and ease of use. ESRD is currently implementing these improvements through AFOSR sponsorship. Once the modifications are in place, the CAI endorsement will result in the use of *Stress Check* for bonded joint analysis throughout the aeronautics industry. The CAI team has involved extensive DoD and industry participation. Representation has included the Air Force Research Laboratory, the Naval Air Systems Command, Lockheed Martin companies in Fort Worth and Marietta; Boeing companies in Seattle, St. Louis, and Long Beach; Northrop Grumman companies in Bethpage, N.Y. and El Segundo, Calif. and General Electric Aircraft Engines in Cincinnati.

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AFOSR Lauded for Scientific Program Management

AFOSR

"Excellent"
"National Resource"
"High Value"

This year's Air Force Scientific Advisory Board (SAB) evaluation netted a very postive review of AFOSR's basic research program management. In March, the board released its report based on panel reviews which assessed the quality and long-term relevance of the Air Force science and technology program. The quality factors include the organization's science, people, strategy, resources, focus, facilities and results.

The review, which annually evaluates half of the laboratory research programs, is conducted on behalf of the Air Force Secretary and Chief of Staff by the SAB and Air Force Chief Scientist.

"We received very favorable comments regarding our cooperation with the rest of the Air Force Research Laboratory as well as plaudits for our university research," said Dr. Joseph P. Janni, the AFOSR Director.

The report specifically cited AFOSR for accomplishing outstanding program integration with the other AFRL technology directorate research efforts and the value of its exemplary work to the Air Force.

"Such a favorable review would not have occurred without the excellence and dedication of our scientific program managers," Dr. Janni added. "Their professional collaborations and partnership endeavors are making a real difference in improving the quality of our research efforts and accomplishments."

Additional SAB report comments on the AFRL review included:

- "Important technical advances have been made"
- "Air Force officers as scientists and engineers are an important part of lab quality"
- The TechSat 21 program was lauded as "revolutionary" and cited as a "technical highlight" The small satellite program represents a different way of doing business, intergrating research programs across AFOSR, and the Space and Sensors Directorates.

Research Highlights

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Research Highlights is published every two months by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission. *Research Highlights* is available on-line at:

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